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## **Additional Data on the Fauna of Bivalve Mollusks of the Russian Continental Coast of the Sea of Japan: Middle Primorye and Nakhodka Bay**

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**Abstract** The bivalve molluscan fauna of Vrangeli Bay, a small embayment in the eastern part of Peter the Great Bay (Nakhodka Bay), and in several localities along the coast of middle Primorye (Maritime Province, both in north-western part of the Sea of Japan, was studied based on 185 dredge and SCUBA-diving samples (in all, 40 stations). A total of 58 species of bivalves were identified. Eight species are recorded for the first time from the coast of middle Primorye. Comparative analysis of bathymetric ranges of bivalve mollusks from different parts of the Sea of Japan is carried out, and presence of shells believed to be subfossil and redeposition of Recent shell remains are discussed. Cold-water and relatively cold-water mollusks occur in Vrangeli Bay, a protected bay, in shallow waters which can be explained by the influence of the cold Primorsky Current. The faunal differences between eastern and western parts of Peter the Great Bay are emphasized. Taxonomic and biogeographic comments on some species are given.

**Key words:** bivalve mollusks, biogeography, bathymetric ranges, taxonomy

### **Introduction**

Despite the appearance of the monograph of Scarlato (1981) dealing with bivalve fauna of all Russian (former Soviet) Far Eastern Seas, and a number of recent publications, species composition, taxonomy and distributional patterns of bivalve mollusks of the Russian part of the Sea of Japan (East Sea) remain poorly known as compared to the Japanese coast. Peter the Great Bay (the southern part of the Primorye Territory, Maritime Province) is the only thoroughly investigated area; however, species composition data and distribution of mollusks refer mostly to some bays and localities within Peter the Great Bay - Possjet Bay (Golikov & Scarlato, 1967; 1971), Far East State Marine Reserve area (Moskaletz, 1984; 1990), and Vostok Bay (Evseev, 1976). There are also several papers describing selected bivalves from Peter the Great Bay or treating their nomenclature and systematics based on materials mainly from the Bay (Bartsch, 1929; Scarlato, 1972; Ivanova & Moskaletz, 1984; Lutaenko, 1993; Kafanov & Lutaenko, 1996, 1997a, b; Kamenev, 1996). We undertook a special faunal and taphonomic investigation on beach molluscan thanatocoenoses in Possjet, Amur, Ussuri and Vostok Bays (Lutaenko, 1990; 1994a, b).

As for the areas situated north of Peter the Great Bay, we should mention a paper of Romeyko (1985). Unfortunately, this author performed only a biogeographical and ecological analysis of bivalve fauna, without presentation of species lists. Therefore, we are not able to define the exact geographical distributions of many species along the Russian continental part of the Sea of Japan or to compile species lists for each coastal area or bay. These gaps can be filled only by Scarlato (1981) data, but they are outdated and additional faunal studies are needed.

The bivalve fauna of the southern part of Sakhalin Island (Golikov & Scarlato, 1985) and small Moneron Island in the north-western part of the Sea of Japan (Ivanova, 1985; Romeyko & Kamenev, 1985) were studied more completely due to the work of hydrobiological

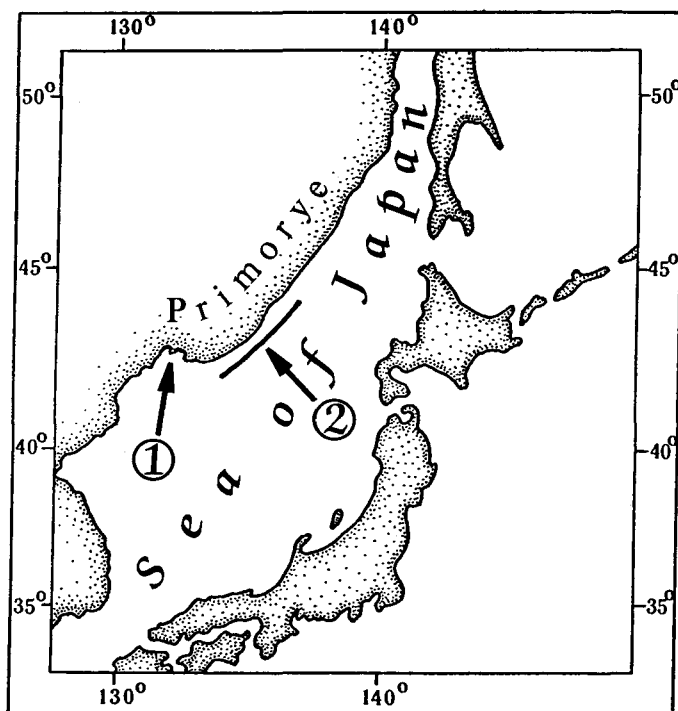


Fig. 1. Map of the Sea of Japan with areas of collecting mollusks (1 - Peter the Great Bay, 2 - middle Primorye coast).

teams of the Institute of Marine Biology, Far East Branch of the Russian Academy of Sciences (former USSR Academy of Sciences) during the 1970's and 1980's. Evseev (1981) described in detail the Holocene history of bivalve molluscan fauna of the middle part of Primorye Territory, but some species names given in his work are without descriptions or illustrations and require a taxonomical and nomenclatural revision. The present paper deals with new materials on the species composition, distribution and habitats of bivalve mollusks in two areas: Vrangal Bay and middle Primorye (Fig. 1). Vrangal Bay is situated within Nakhodka Bay - one of the largest embayments inside Peter the Great Bay, but bivalve mollusks have not been studied in this area except for the records of some commercial species (Razin, 1934). Biogeographically, middle Primorye is located in another unit in terms of zonal biogeography (Scarlato, 1981) and environmental conditions are quite different from Peter the Great Bay.

### Materials and Methods

Materials for this study were collected in Vrangal Bay during August 1995 aboard the R/V Kassis (24 stations) (Fig. 2) and along the coast of middle Primorye (Figs. 3-5) during September-October 1995 aboard the R/V Akademik Oparin, 18th cruise (16 stations). A total of 185 samples were treated containing both empty shells and live mollusks. Living specimens were fixed with 70 % ethanol (middle Primorye) or formalin (Vrangal Bay). In Vrangal Bay samples were collected using a small dredge and simultaneously, at the same stations, with a bottom-sampler by SCUBA-divers. During the 18th cruise of the R/V Akademik Oparin, samples were collected qualitatively by SCUBA-divers and by the same dredge. One station was sampled by trawl (sta. 39). At a majority of SCUBA-diving stations, benthic organisms were collected at different depths and bottom

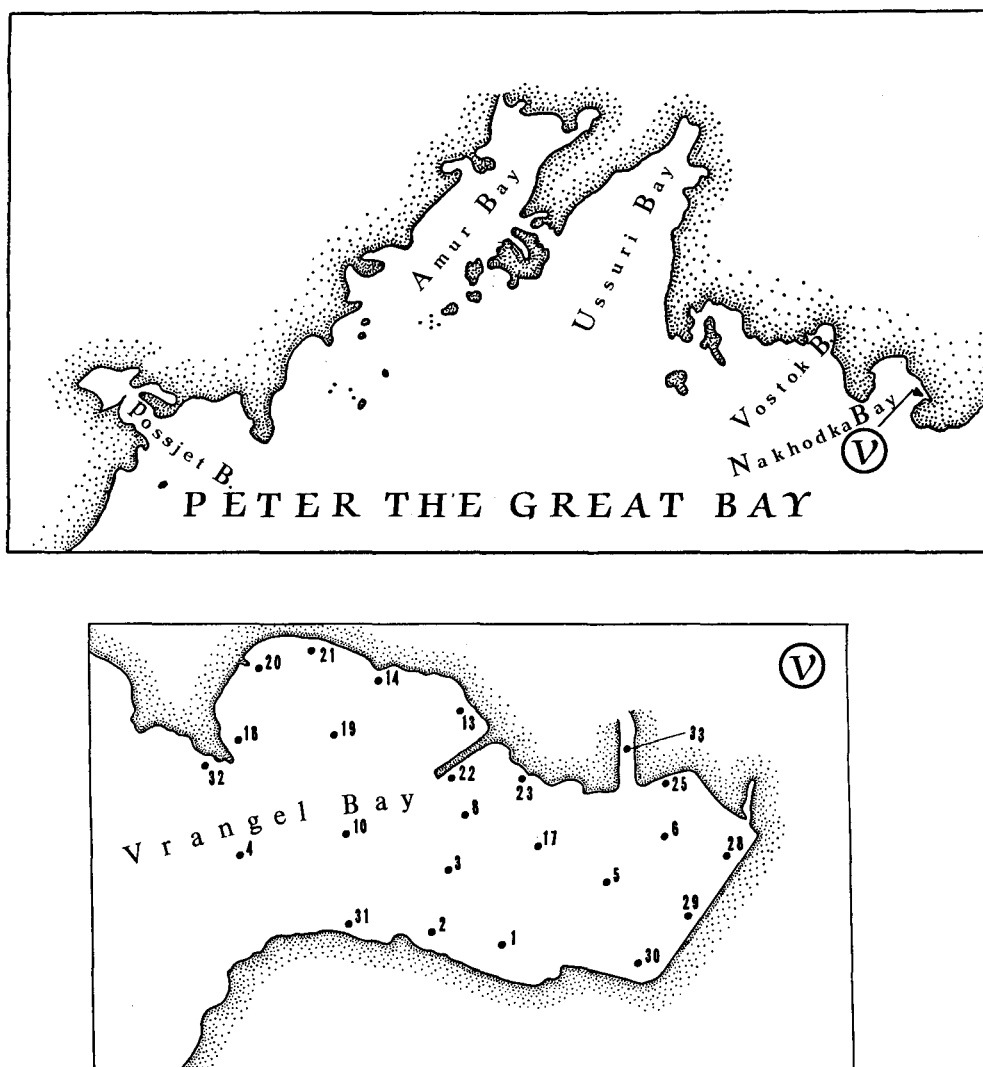


Fig. 2. Map of Peter the Great Bay with sampling stations in Vranghel Bay (V: Vranghel Bay).

types, and, in this case, several samples were taken at one station. The samples were sieved on board of the ship and sorted into dead (empty shells) and live specimens. Samples from Vranghel Bay were first fixed aboard ship and then sieved in the laboratory of the Institute Museum, Institute of Marine Biology, FEB RAS. The majority of live mollusks were dried after a fixation period of 2-4 months.

The collection of bivalve mollusks from both areas studied is stored in the Institute Museum, Institute of Marine Biology, FEB RAS.

Abbreviations used throughout the text are as follows: MIMB - the Institute Museum, Institute of Marine Biology, FEB RAS (Vladivostok); ZMFU - Zoological Museum, Far East State University (Vladivostok); M.e. - material examined; s. - specimen(s).

#### Regional Setting

The Russian continental coast of the Sea of Japan is clearly divided into two geomorphological

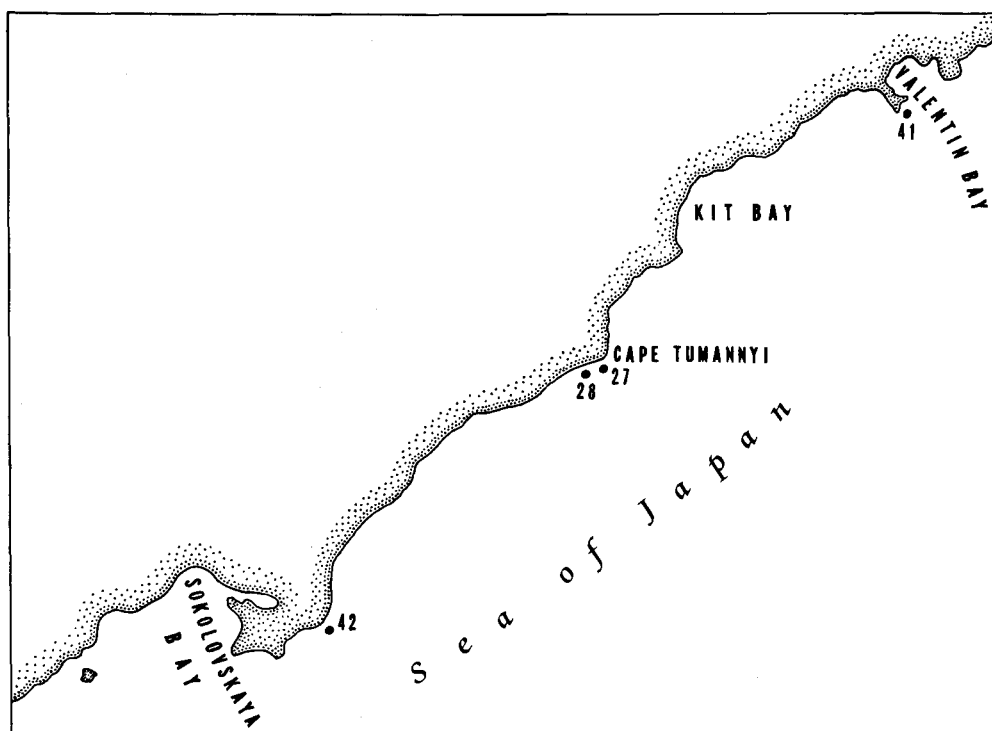


Fig. 3. Map of the middle Primorye with sampling stations 27, 28, 41, 42 (southern part of the area studied).

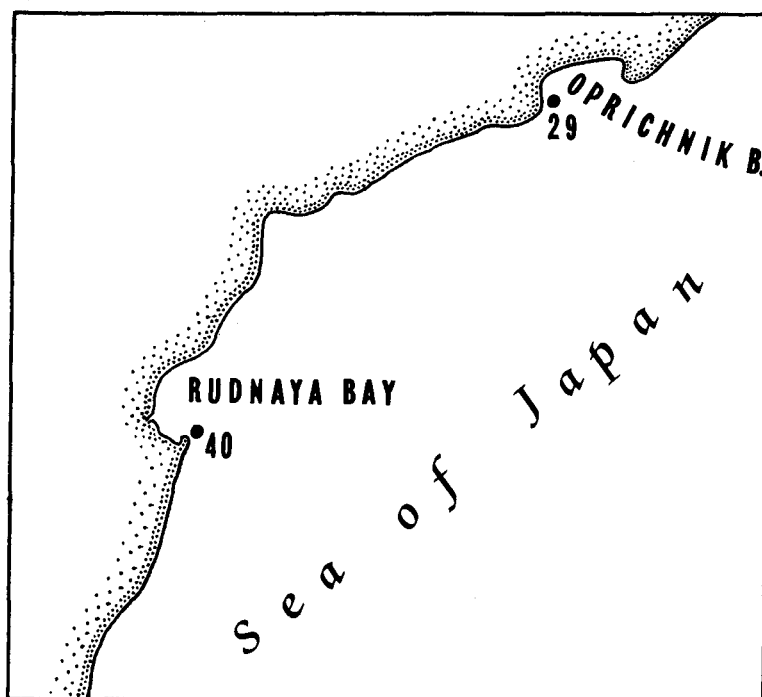


Fig. 4. Map of the middle Primorye with sampling stations 9, 40 (northern part of the area studied).

Table 1. Sampling stations of the R/V Akademik Oparin made in middle Primorye (Maritime Province) during 18th cruise (September - October 1995).

STATION	LATITUDE, N	LONGITUDE, W
27	42°58'	134°06'
28	42°58'	134°06'
29	44°26'	135°59'
30	44°26'	135°59'
31	44°26'	135°59'
32	44°32'	136°11'
33	44°34'	136°13'
34	44°44'	136°20'
35	44°46'	136°27'
36	44°47'	136°19'
37	44°56'	136°34'
38	44°55'	136°33'
39	44°51'	136°37'
40	*	*
41	43°05' **	134°18' **
42	42°53'	133°97'

\* Location of sta. 40 was not determined precisely (Rudnaya Bay, near Brinera Cape).

\*\* Near Titova Cape

regions with different hydrological regimes and environmental conditions. The northern region is characterized by a weakly indented coastline with open bays representing, in most cases, concavities of the coast, not sheltered from winds. Abrasional shores with rocky cliffs of significant height and comparatively narrow gravel and boulder beaches predominate along nearly the entire coastline; accumulative areas (low marine terraces) occur in coastal concavities (Papunov, 1987).

Bays, relatively enclosed from wind waves and cut into the coast (Plastun, Dzhigit, Olga, Vladimir, Valentin Bays, etc.), were formed by the ingress of the sea into erosional river valleys (Ignatova & Chudaeva, 1983; Korotky & Khudyakov, 1990). A large number of small streams originating from mountain slopes and several large rivers flow into the sea in this area, but do not significantly influence the hydrological conditions of the shallow waters.

The northern shelf of the Sea of Japan is narrow (average 35 km), and occasionally narrows to only 10–11 km. The depth of the shelf edge varies from 100 to 200 m. Coarse-grained sand and pebble deposits that accumulated during the maximum of last glaciation, when the sea level dropped 120–130 m (Korotky et al., 1980), are distributed along the marginal areas of the shelf. In the upper part of the shelf, basal rocks are frequently found with thin layers of clastic deposits (Ignatova & Chudaeva, 1983). Sandy sediments are limited in their distribution along the coast of middle Primorye. Silty sands are found in the wide area of the central shelf, sometimes having an admixture of pebbles. Muddy sediments occupy the bottom of semi-enclosed bays.

Two cold currents wash the coast of Primorye - Primorskoe (Maritime Province Cold Current, according to Hidaka, 1966) and Schrenck Currents (= Liman Cold Current) (Yurasov & Yarchin, 1991). The main stream of Primorskoe Current flows at a distance of 15–20 km from the coast along the marginal part of the shelf and mainly below 50–60 m. In the upper part of the shelf (above 20 m), there is a compensating anti-current of warm water; in this bathymetric range, water can warm to 15–17°C (Evseev, 1981). Generally, cold currents in the Sea of Japan are much weaker than warm currents (Hidaka, 1966). Salinity in open areas approaches normal marine and is 33–34 ‰ in the zone affected by the Primorskoe Current, but it can decrease in bays for a short

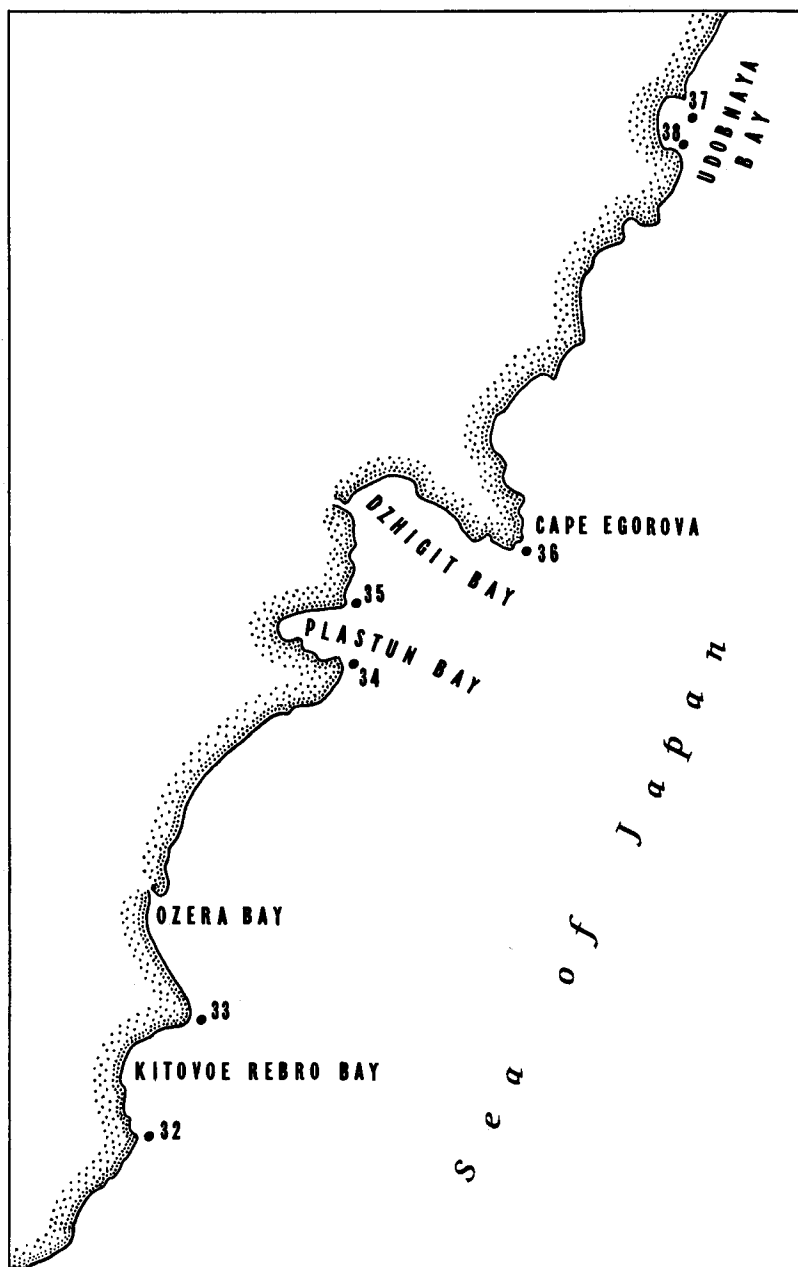


Fig. 5. Map of the middle Primorye with sampling stations 32– 38 (most northern part of the area studied).

time during periods of rains.

The southern geomorphological area includes Peter the Great Bay with six large embayments - Possjet, Amur, Ussuri, Strelok, Vostok, and Nakhodka Bays. Vrangeli Bay is located on the eastern coast of Nakhodka Bay and is strongly influenced by anthropogenic pressure due to the activity of Port Vostochny. The temperature regime of Peter the Great Bay is characterized by the contrasting conditions. During winter, coastal waters become equal in temperature approaching arctic

conditions. During summer, waters of semi-enclosed shallow bays warm strongly (to 28°C in August) (Biryulin et al., 1970). At the same time, in the subtidal zone of open areas, August temperatures reach 15–17°C.

Salinity of the surface waters depends significantly on river runoff. During the summer, upper layers 10–15 m thick may have low salinity due to typhoons and rain but these layers of unstable salinity are rapidly destroyed by wave action (Podorvanova et al., 1989). In winter, salinity seems to be equal in all areas of Peter the Great Bay. Bottom deposits in Vrangell Bay are represented mainly by mud and muddy sand in central parts of the bay, and by sand and gravel near coastline (Rynkov et al., 1974).

### SYSTEMATIC ACCOUNT

Class Bivalvia

Subclass Protobranchia

Superfamily Nuculoidea Gray, 1824

Family Nuculidae Gray, 1824

#### *Nucula (Ennucula) ovatotruncata* (Scarlato in Volova et Scarlato, 1980)

Records. Vrangell Bay: sta. 5, 10, 13, 16, 19, 30, 33.

Occurrence. This species was found at a bathymetric range of 4.5 – 17.5 m, in sandy and muddy sediments.

M.e. 10 s.

#### *Acila (Truncacila) insignis* (Gould, 1861)

Records. Vrangell Bay: sta. 14, 23.

Occurrence. One live specimen was taken in 4 – 6 m, in sand.

Empty shell is found at a depth of 7.5 m, on rocky bottom.

M. e. 2 s.

Superfamily Nuculanoidea H. Adams et A. Adams, 1858

Family Nuculanidae H. Adams et A. Adams, 1858

Subfamily Nuculaninae H. Adams et A. Adams, 1858

#### *Nuculana (Nuculana) sadoensis* (Yokoyama, 1926)

Records. Middle Primorye: sta. 39.

Occurrence. One live specimen was taken in 111 m, in muddy sand with pebbles.

M. e. 1 s.

Subfamily Yoldiinae Habe, 1977

#### *Yoldia (Cnesterium) johanni* Dall, 1925

Records. Vrangell Bay: sta. 13; middle Primorye: sta. 41.

Occurrence. It was taken in Vrangell Bay in 4.5 m, in sand, and near Cape Titova in middle Primorye this species was found in 15 m.

Remarks. Scarlato (1981) noted that *Y. johanni* inhabits the Sea of Japan, northern Japan and the southern Kuril Islands (Iturup Island). Matsukuma et al. (1991) also mentioned western coast of the Kamchatka Peninsula (54° 30' N, 155°00' E) as the northernmost locality based on Ito (1966; non vidi) record.



M. e. 2 s.

***Yoldia (Cnesterium) notabilis* Yokoyama, 1922**

Records. Vrangal Bay: sta. 1-4, 10, 17, 30.

Occurrence. Live mollusks were taken in muddy sand and mud in a depth range of 10 – 17.5 m; one empty shell was collected in 16.5 m, in sand.

Remarks. This species was described by Scarlato (1981) as a new subspecies, *Yoldia (Cnesterium) keppeliana pseudonotabile* (holotype originated from Nakhodka Bay). Kafanov (1991) stated that part of specimens of *Y. keppeliana pseudonotabile* in Scarlato's collection refers to *Yoldia (Cnesterium) keppeliana* Sowerby, 1904, but mostly to *Y. notabilis*.

M. e. 7 s.

Subclass Pterimorphia

Superfamily Mytiloidea Rafinesque, 1815

Family Mytilidae Rafinesque, 1815

Subfamily Mytilinae Rafinesque, 1815

***Crenomytilus grayanus* (Dunker, 1853)**

Records. Vrangal Bay: sta. 31; middle Primorye: sta. 29, 34-36, 42.

Occurrence. Empty shells of this common mussel were found among sand and pebbles in Vrangal Bay, at a depth 7 m. Live mollusks were collected in Oprichnik, Plastun, Dzhigit, and Sokolovskaya Bays in total bathymetric range of 0.5 – 12 m, on rocky bottom and among seagrass *Phyllospadix iwatensis*.

M. e. 27 s.

***Mytilus (Mytilus) edulis* L., 1758 s.l.**

Records. Vrangal Bay: sta. 6, 30, 33.

Occurrence. Empty shells were taken in 7.5 – 25 m, in muddy sand and mud.

M. e. 3 s.

Subfamily Crenellinae Gray, 1840

***Vilasina pillula* Bartsch in Scarlato, 1960**

Records. Middle Primorye: sta. 29, 30, 32, 34-38, 41.

Occurrence. This species was taken in Oprichnik, Kitovoe Rebro, Plastun, Dzhigit, and Udobnaya Bays, and near Cape Titova in total depth range of 0.5 – 20 m, on rocky bottom, occasionally among seagrass *Phyllospadix iwatensis* and in the belt of algae *Tichocarpus*.

Remarks. The species is recorded for the coast of middle Primorye for the first time. According to Scarlato (1981), it has been known in the Sea of Japan only within Peter the Great Bay, Chikhacheva (De-Kastri) Bay and along the western coast of Sakhalin Island.

M. e. More than 100 s.

Subfamily Modiolinae Keen, 1958

***Modiolus (Modiolus) kurilensis* Bernard, 1983**

Records. Vrangal Bay: sta. 31.

Occurrence. One empty shell was taken in 7 m.

Remarks. We do not support the viewpoint of Coan & Scott (1997) that *M. kurilensis* is a synonym of *Modiolus modiolus* (L., 1758).

M. e. 1 s.

Superfamily Glycymeridoidea Newton, 1922

Family Glycymerididae Newton, 1922

Subfamily Glycymeridinae Newton, 1922

***Glycymeris (Glycymeris) yessoensis* (Sowerby, 1889)**

Records. Vrangal Bay: sta. 32.

Occurrence. One empty shell was taken in 9 m, among small pebbles.

M. e. 1 s.

Superfamily Arcoidea Lamarck, 1809

Family Arcidae Lamarck, 1809

Subfamily Arcinae Lamarck, 1809

***Arca boucardi* Jousseaume, 1894**

Records. Vrangal Bay: sta. 5; middle Primorye: sta. 36, 41, 42.

Occurrence. Empty shells were taken in Vrangal Bay in 11 m, in mud with sand admixture. In middle Primorye it was found in Sokolovskaya and Dzhigit Bays, and near Cape Titova, in total bathymetric range of 10 – 18 m, on rocky bottom.

Remarks. This species has been known from Peter the Great Bay in Russian waters of the Sea of Japan (Scarlato, 1981). Dzhigit Bay (44°46') is the northernmost locality of *A. boucardi* on the continental coast of the sea. We also established that this species occurs on the coast of Kunashir Island, the southern Kuril Islands (based on the collection of the ZMFU - Darkina and Lutaenko, 1996). The findings of *A. boucardi* in Busse Lagoon (southern Sakhalin, Okhotsk Sea) (Evseev, 1981) and in coastal waters of Moneron Island (Romeyko & Kamenev, 1985) extend its distributional range northward. These new records make it possible to change the zonal-geographical characteristics of the species from subtropical (Scarlato, 1981) to subtropical-lowboreal (Fig. 6).

M. e. 8 s.

Superfamily Anomioidea Rafinesque, 1815

Family Anomiidae Rafinesque, 1815

Subfamily Placunanomiinae Beu, 1967

***Pododesmus macrochisma* (Deshayes, 1839)**

Records. Middle Primorye: sta. 29, 34, 40–42.

Occurrence. This species is very common to the middle Primorye area and was found in Sokolovskaya, Rudnaya, Plastun Bays, and near Cape Titova on rocky bottom. Empty shells were taken at a depth range of 9 – 15 m, live specimens - in 10 – 32m. Fedorov (1991) found this species along the coast of Primorye at a depth range 25 – 70 m.

M. e. 20 s.

Superfamily Ostreoidae Rafinesque, 1815

Family Ostreidae Rafinesque, 1815

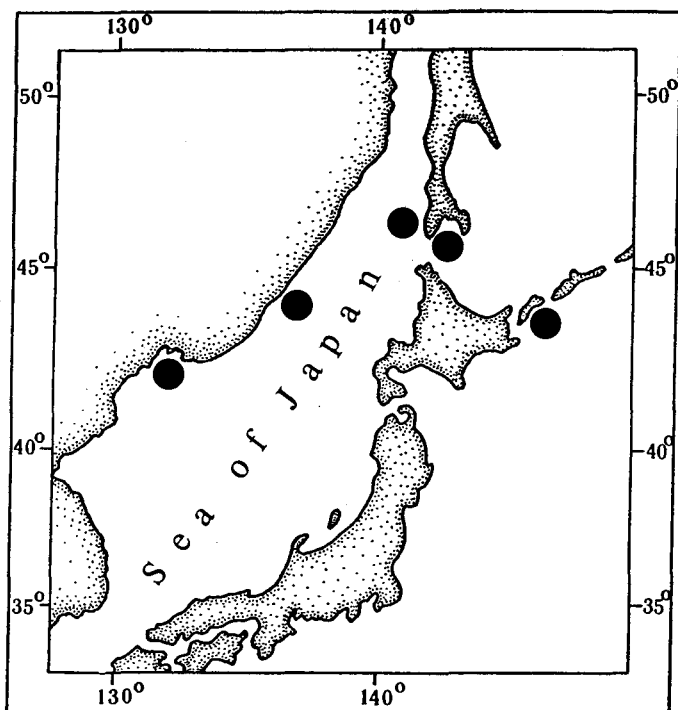


Fig. 6. Distribution of *Arca boucardi* Jousseaume (Arcidae) in the Russian Far Eastern regions.

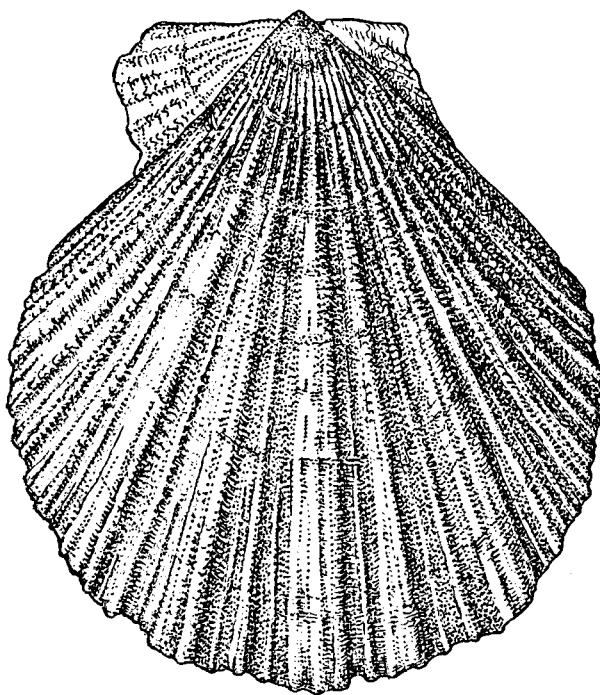


Fig. 7. *Chlamys (Chlamys) albida* (Dall) (Pectinidae): middle Primorye, sta. 39, depth 111 m. Left valve, height 38 mm. MIMB.

Subfamily Ostreinae Rafinesque, 1815

***Crassostrea gigas* (Thunberg, 1783)**

Records. Vrangal Bay: sta. 4–5, 10, 14, 20, 22, 23.

Occurrence. Only empty shells and shell fragments of this species were taken in 4 – 25 m, in mud and sand.

M. e. 13 s.

Superfamily Pectinoidea Wilkes, 1810

Family Pectinidae Wilkes, 1810

Subfamily Chlamydinae von Teppner, 1922

***Chlamys (Chlamys) albida* (Dall, 1906)**

Fig. 7

Records. Middle Primorye: sta. 39.

Occurrence. Empty shell was taken in 111 m, in muddy sand with pebbles.

Remarks. This species was earlier registered only in the northern part of the Sea of Japan (Tatarsky (Mamiya) Strait) (Scarlato, 1981).

M. e. 1 s.

***Chlamys (Chlamys) cf. behringiana* (Middendorff, 1849)**

Plate I, figs. 1–3

Records. Middle Primorye: sta. 39.

Occurrence. Empty shells were taken in 111 m, in muddy sand with pebbles.

Remarks. Kafanov (1991) stated that *Pecten (Chlamys) hericeus* var. *strategus* Dall, 1898 regarded by Scarlato (1960, 1981) and Habe (1977) as a distinct species, *Ch. stratega*, is a synonym of *Ch. behringiana*. According to Scarlato (1981), *Ch. stratega* inhabits the continental coast of the Sea of Japan, but *Ch. behringiana* has not been recorded in the sea except for unchecked record in the catalogue of mollusks of the ZMFU (Darkina and Lutaenko, 1996) and doubtful record of a new subspecies *Chlamys behringiana scarlatovi* Myasnikov, Zgurovsky et Temnych, 1992 (Myasnikov et al., 1992) for which holotype was not fixed and location of syntypes are unknown. Our identification needs further verification.

M. e. 5 s.

***Chlamys (Chlamys) chosonica* Kuroda, 1932**

Plate I, fig. 5

Records. Middle Primorye: sta. 39.

Occurrence. Both live specimens and empty shells were taken in 111 m, in muddy sand with pebbles.

M. e. 42 s.

***Chlamys (Swiftopecten) swifti* (Bernardi, 1858)**

Records. Middle Primorye: sta. 27, 29, 34–37, 41, 42.

Occurrence. This species was collected in Sokolovskaya, Oprichnik, Plastun, Dzhigit, Udobnaya Bays, and near Capes Tumannyi and Titova in total bathymetric range of a 0.5 – 20 m, on rocky bottom.

M. e. 37 s.

Subfamily Propeamussiinae Abbot, 1954

***Parvamussium (Polynemamussium) alaskense (Dall, 1871)***

Records. Middle Primorye: sta. 39.

Occurrence. Live specimens were taken in 111 m, in muddy sand with pebbles.

M. e. 4 s.

Subfamily Fortipectininae Masuda, 1963

***Mizuhopecten yessoensis (Jay, 1857)***

Records. Vrangal Bay: sta. 10; middle Primorye: sta. 33.

Occurrence. Empty shells were taken in subtidal zone of Kitovoe Rebro Bay, and in Vrangal Bay in 17.5 m.

Remarks. According to Scarlato (1981), this species extends along the continental coast of the Sea of Japan as far north as Rudnaya Bay, although it occurs also in Chikhacheva (De-Kastri Bay), the northernmost locality in the sea. Kitovoe Rebro Bay is a new northern locality of the species.

M. e. 2 s.

Subclass Heterodonta

Superfamily Lucinoidea Fleming, 1828

Family Ungulinidae H. Adams et A. Adams, 1857

***Felaniella usta (Gould, 1861)***

Records. Vrangal Bay: sta. 5, 14, 17, 21, 32; middle Primorye: sta. 41.

Occurrence. Empty shells were taken in Vrangal Bay in 3.5–11 m in sandy mud, sand and pebbles, and near Cape Titova in 15 m, on rocky bottom.

M. e. 40 s.

Family Thyasiridae Dall, 1901

***Axinopsida subquadrata (Adams, 1862)***

Records. Vrangal Bay: sta. 1, 3, 6, 8, 10, 16, 18, 24, 25, 30, 33; middle Primorye: sta. 29.

Occurrence. This species is very common in Vrangal Bay and was collected there at a depth range of 4 – 25 m, in mud, sand and muddy sand; in middle Primorye one empty shell was taken in Oprichnik Bay, in 17 m, in muddy sand.

M. e. 23 s.

Superfamily Galeommatoidea Gray, 1840

Family Lasacidae Gray, 1847

***Kellia japonica Pilsbry, 1895***

Records. Middle Primorye: sta. 34, 36, 37, 41.

Occurrence. This species was taken in Plastun, Dzhigit, Udobnaya Bays, and near Cape Titova in 1 – 15 m, on rocky bottom.

M. e. 8 s.

Family Montacutidae Clark, 1855

***Mysella* (?) sp.**

Records. Middle Primorye: sta. 41.

Occurrence. One empty shell was taken near Cape Titova, in 15 m.

M. e. 1 s.

Superfamily Carditoidea Fleming, 1828

Family Carditidae Fleming, 1828

Subfamily Venericardiinae Chavan, 1969

***Cyclocardia* (*Crassicardia*) *crassidens* (Broderip et Sowerby, 1829)**

Records. Middle Primorye: sta. 40, 42.

Occurrence. Live specimens were taken in Sokolovskaya and Rudnaya Bays, in 32 – 50 m, on rocky bottom.

Remarks. We follow Coan & Scott (1997) regarding *Crassicardia* Savizky, 1979 as only a subgenus.

M. e. 7 s.

Superfamily Cardioidea Lamarck, 1809

Family Cardiidae Lamarck, 1809

Subfamily Laevicardiinae Keen, 1936

***Clinocardium* (*Keenocardium*) *californiense* (Deshayes, 1839)**

Plate II, fig. 4

Records. Vrangal Bay: sta. 5, 14, 17, 18, 23–25, 29, 31, 33; middle Primorye: sta. 29, 37, 41.

Occurrence. In Vrangal Bay, empty shells were taken in 4 – 12.5 m, in muddy sand, pebbles and sand; live specimens were collected in 7 – 12.5 m, in muddy sand and sand. Empty shells were found in middle Primorye at a depth range of 3 – 15 m, in Oprichnik and Udobnaya Bays, and near Cape Titova, on rocky bottom. One live specimen was collected near Cape Titova in 30 m, in sand.

M. e. 17 s.

***Clinocardium* (*Ciliatocardium*) *ciliatum* (Fabricius, 1780)**

Records. Middle Primorye: sta. 39.

Occurrence. One empty shell was taken in 111 m, in muddy sand with pebbles.

Remarks. This widely distributed boreal-arctic species occurring both the Atlantic and Pacific Oceans was subdivided by Kafanov (1981) into six morphological groups formally designated as subspecies. One of the subspecies described by Kafanov (in Scarlato, 1981), inhabits the Sea of Japan (*Clinocardium*(*Ciliatocardium*) *ciliatum* *tschuktchense* (Kafanov in Scarlato, 1981)) in its northern part, southern Primorye and the coast of Hokkaido. Middle Primorye is a new locality of this species except for records from the Holocene deposits (Evseev, 1981).

M. e. 1 s.

***Clinocardium* (*Ciliatocardium*) *likharevi* Kafanov in Scarlato, 1981**

Records. Middle Primorye: sta. 39.

Occurrence. One live specimen was taken in 111 m, in muddy sand with pebbles.

Remarks. This doubtful species might be a synonym of *C. ciliatum*. This is the first record for the middle Primorye area.

M. e. 1 s.

Subfamily Serripedinae Kafanov, 1975

***Serripes groenlandicus* (Mohr, 1786)**

Plate II, figs. 5

Records. Vrangal Bay: sta. 6, 13, 17; middle Primorye: sta. 39.

Occurrence. In Vrangal Bay, empty shells were taken at a depth range of 4.5 – 25 m, in sandy mud and sand; in middle Primorye, empty shells were found in 111 m, in muddy sand with pebbles.

Remarks. According to Scarlato (1981), this species has been known in the Sea of Japan only from the bathymetric range of 14 – 65 m. See about authorship of this species: Coan & Scott, 1997.

M. e. 6 s.

Superfamily Mactroidea Lamarck, 1809

Family Mactridae Lamarck, 1809

Subfamily Mactrinae Lamarck, 1809

***Mactra (Mactra) chinensis* Philippi, 1846**

Records. Middle Primorye: sta. 27.

Occurrence. Live specimens were found near Cape Tumannyi in 9 – 12 m, in sand.

Remarks. Cape Tumannyi is the northernmost locality of this species on the continental coast of the Sea of Japan; according to Scarlato (1981), *M. chinensis* has been known as far north as Sokolovskaya Bay.

M. e. 1 s.

***Spisula (Pseudocardium) sachalinensis* (Schrenck, 1862)**

Records. Middle Primorye: Dzhit Bay (between sta. 35 and sta. 36).

Occurrence. Empty shells were collected as beach drift.

Remarks. Dzhit Bay is a new northern locality of *S. sachalinensis*; according to Scarlato (1981), this species has been known as far north as Olga Bay.

M. e. 2 s.

Subfamily Pteropsellinae Keen, 1969

***Raeta (Raetellops) pulchella* (Adams et Reeve, 1850)**

Records. Vrangal Bay: sta. 6, 10, 13, 17, 19, 24, 30, 33.

Occurrence. This species was taken in total bathymetric range of 4.5 – 25 m, in mud, sand and muddy sand.

M. e. 14 s.

Superfamily Tellinoidea Blainville, 1814

Family Tellinidae Blainville, 1814

Subfamily Tellininae Blainville, 1814

***Cadella lubrica* (Gould, 1861)**

Records. Middle Primorye: sta. 33, 34.

Occurrence. Live specimens were taken in Kitovoe Rebro and Plastun Bays, in 6 m, in coarse-grained sand.

Remarks. This species has been as far north as Vladimir Bay (Scarlato, 1981). Plastun Bay is a new northernmost locality on the continental coast of the Sea of Japan.

M. e. 8 s.

Subfamily Macominae Olsson, 1961

***Macoma (Macoma) calcarea* (Gmelin, 1791)**

Records. Middle Primorye: sta. 39.

Occurrence. Empty (?subfossil) shells were taken in 111 m, in muddy sand with pebbles.

M. e. 33 s.

***Macoma (Macoma) incongrua* (Martens, 1865)**

Records. Vrangal Bay: sta. 17.

Occurrence. One empty shell was taken in 11.5 m, in muddy sand.

M. e. 1 s.

***Macoma (Macoma) scarlatoi* Kafanov et Lutaenko, 1997**

Plate II, fig. 8

Records. Vrangal Bay: sta. 1, 3, 6, 10, 13, 22, 24, 25.

Occurrence. Live specimens were taken in total bathymetric range of 7 – 25 m, in mud, muddy sand and sand; empty shells were collected in 4.5 – 17.5 m.

Remarks. *M. scarlatoi* is nom. nov. pro *Macoma orientalis* Scarlato in Golikov et Scarlato, 1967 non *Macoma (Cymatoica) orientalis* (Dall, 1890) (see Kafanov and Lutaenko, 1997).

M. e. 16 s.

***Macoma (Macoma) golikovi* Scarlato et Kafanov, 1988**

Plate II, fig. 11

Records. Vrangal Bay: sta. 5.

Occurrence. Empty shell (one valve) was found in 11 m, in muddy sand.

Remarks. This species was originally described by Scarlato (1981) as *Macoma orbiculata* Scarlato, 1981 from southern Sakhalin Island (both Japan and Okhotsk Seas sides). Due to preoccupation, Scarlato and Kafanov (1988) proposed a new name, *M. golikovi* nom. nov. pro *Macoma orbiculata* Scarlato, 1981 non Kanno, 1958. We suppose that *Macoma lukini* Kamenev, 1990 known from the Kuril and Commander Islands, Avacha Bay (Kamchatka) and Tauiskaya Inlet (Okhotsk Sea) in the Russian Far East seas, is a synonym of *M. golikovi* (see figures in Scarlato, 1981 and Kamenev, 1990, 1995). Evseev (1981) certainly mentioned *M. golikovi* under the heading *Macoma arnheimi* Dall (p. 134, pl. I, figs. 1, 4). *M. arnheimi* was discovered in the Holocene deposits of Cape Povorotny (eastern part of Peter the Great Bay) and along Primorye coast as far north as Zerkalnaya Bay. Probably, *M. golikovi* became extinct along the continental coast of the Sea of Japan during the mid-Holocene warming,



but it still exists in high-boreal regions of the western Pacific Ocean. Amano (1996) also suggested that *Macoma orbiculata* Scarlato migrated to the Sea of Japan only after the Late Pleistocene. On the other hand, *M. lukini*, *M. golikovi* and *M. arnheimi* of Evseev (1981) are similar in general features to *Macoma obliqua* (Sowerby, 1817) from the eastern Pacific (see also: Kamenev, 1995, p. 10) originally described from the Pleistocene deposits of Europe (Coan, 1971). Kamenev (1995) regarded *M. lukini* as a Pacific amphiboreal species occurring off the shores of both Asia and North America, but he did not discuss the relationships between *M. golikovi* (= *M. orbiculata* Scarlato, 1981) and *M. lukini*.

M. e. 1 s.

***Macoma (Macoma) middendorffi* Dall, 1884**

Plate I, fig. 4; plate II, fig. 1

Records. Vrangal Bay: sta. 31; middle Primorye: sta. 39.

Occurrence. Empty shells were taken in Vrangal Bay in 7 m, in gravel and sand, and in middle Primorye in 111 m, in muddy sand with pebbles.

Remarks. This species has been known in Primorye only from Olga Bay (Scarlato, 1981). According to Evseev (1981), it is also found in the Holocene deposits of Vostok Bay and along the coast of Primorye as far north as Zerkalnaya Bay at a depth range of approximately 10 – 60 m. We established that *M. middendorffi* occurs on the coast of Peter the Great Bay - Boysman Bay and Popov Island (beach drift; collection of the ZMFU).

M. e. 2 s.

Family Semelidae Stoliczka, 1870

***Theora fragilis* A. Adams, 1855**

Records. Vrangal Bay: sta. 6, 8, 10, 13, 17, 24, 25, 28, 33.

Occurrence. Living specimens are very abundant in Vrangal Bay and were taken at a bathymetric range of 4.5 – 25 m, in mud and muddy sand, sometimes in finely grained sand.

M. e. 79 s.

Family Psammobiidae Flemming, 1828

Subfamily Sanguinolariinae Grant et Gale, 1931

***Nuttallia ezonis* Kuroda et Habe, 1955**

Plate II, fig. 6

Records. Vrangal Bay: sta. 14, 18, 23.

Occurrence. Empty shells were taken in 4 – 7.5 m, in sand.

M. e. 4 s.

Superfamily Solenoidea Lamarck, 1809

Family Cultellidae Davies, 1935

***Siliqua alta* (Broderip et Sowerby, 1829)**

Records. Vrangal Bay: sta. 14.

Occurrence. Empty shell was found in 7.5 m, on rocky (?) bottom.

M. e. 1 s.

Superfamily Veneroidea Rafinesque, 1815  
Family Veneridae Rafinesque, 1815  
Subfamily Chioninae Frizzel, 1936

***Mercenaria stimpsoni* (Gould, 1861)**

Records. Vrangal Bay: sta. 14, 21, 23, 31, 32; middle Primorye: sta. 36.

Occurrence. Empty shells of this species were taken in Vrangal Bay at total bathymetric range of 4 – 9 m, in sand and pebbles; one live specimen was found in Dzhigit Bay, in 9 m, ins and among sea-grass *Zostera*.

Remarks. Dzhigit Bay is a new northern locality of *M. stimpsoni* on the continental coast of the Sea of Japan. This species has been known as far north as Vladimir Bay (Scarlato, 1981).

M. e. 8 s.

***Callithaca adamsi* (Reeve, 1863)**

Records. Vrangal Bay: sta. 2, 4, 10, '18, 20, 23, 24.

Occurrence. Live specimens were found in 4 – 12.7 m, mainly in sand, or muddy sand; empty shells were taken in 4 – 17.5 m, in mud and sand.

M. e. 10 s.

***Protothaca (Notochione) jedoensis* (Lischke, 1874)**

Records. Vrangal Bay: sta. 31; middle Primorye: sta. 29.

Occurrence. Empty shells were taken in Vrangal Bay in 7 m, among pebbles and sand, and in Oprichnik Bay in 3 – 4 m, among boulders.

Remarks. Oprichnik Bay (44°26' N) is a new northern locality of this species on the continental coast of the Sea of Japan. According to Scarlato (1981), *P. jedoensis* has been known only up to 42°50'N along the coast of Primorye.

M. e. 2 s.

***Protothaca (Novathaca) euglypta* (Sowerby, 1914)**

Records. Vrangal Bay: sta. 18; middle Primorye: sta. 27, 29, 36, 37.

Occurrence. Alive mollusks were found in Oprichnik, Dzhigit and Udobnaya Bays, and near Cape Tumannyi, at a total bathymetric range of 4 – 18 m, in sand, among sea-grass *Phyllospadix*, and on the rocky bottom covered with sponges. Empty shells were taken in Vrangal Bay in 4 m, in sand, and in Oprichnik Bay in 3 – 4 m, among boulders.

Remarks. Udobnaya Bay is a new northern locality of *P. euglypta* on the coast of Primorye; it has been known as far north as Olga Bay (Scarlato, 1981).

M. e. 32 s.

Subfamily Tapetinae H. Adams et A. Adams, 1857

***Ruditapes philippinarum* (Adams et Reeve, 1850)**

Records. Vrangal Bay: sta. 13, 20, 23.

Occurrence. Empty shells were taken in 4 – 6 m, in sand; one live specimen was found in 4.5 m.

M. e. 5 s.

***Liocyma fluctuosa* (Gould, 1841) s.l.**

Plate II, fig. 3

Records. Vrangal Bay: sta. 4, 5, 13, 14, 17, 20, 23; middle Primorye: sta. 28.

Occurrence. Empty shells were taken in Vrangal Bay in 4 – 16.5 m, in sand and mud. Live specimens were found near Cape Tummanyi in 47 m, in muddy sand.

M. e. 20 s.

Subfamily Callistinae Nordsieck, 1969

***Callista (Ezocallista) brevisiphonata* Carpenter, 1865**

Records. Vrangal Bay: sta. 32; middle Primorye: sta. 29, 33.

Occurrence. Empty shells were taken in Vrangal Bay in 9 m, among pebbles, and in Kitovoe Rebro Bay. Live specimens were found in Oprichnik Bay in 12 m, in sand.

Remarks. Kitovoe Rebro Bay is a new northern locality of *C. brevisiphonata* known previously as far north as Olga and Vladimir Bays along the coast of Primorye (Scarlato, 1981). *Callista trigonoovata* Scarlato in Volova et Scarlato, 1980 described from Peter the Great Bay (Volova and Scarlato, 1980) appears to be a synonym of *C. brevisiphonata* (Kafanov and Lutaenko, in press).

M. e. 6 s.

Superfamily Myoidea Lamarck, 1809

Family Myidae Lamarck, 1809

Subfamily Myinae Lamarck, 1809

***Mya (Mya) truncata* L., 1758**

Plate I, fig. 6

Records. Vrangal Bay: sta. 19.

Occurrence. One live specimen was taken in 11.5 m, in fine-grained sand.

M. e. 1 s.

***Mya (Mya) uzenensis* Nomura et Zinbo, 1937**

Records. Vrangal Bay: sta. 18, 32.

Occurrence. Empty shells were taken in 4 – 9 m, in sand and pebbles.

Remarks. This species has been known for a long time as *Mya priapus* Tilesius, 1822. We follow Scarlato & Kafanov (1988) and other authors that *priapus* is most likely *Panomya* (family Hiatellidae); Coan & Scott (1997) suggested that *M. uzenensis* described from the Miocene of Japan might be a synonym of *Mya pseudoarenaria* Schlessch, 1931.

M. e. 2 s.

***Mya (Arenomya) japonica* Jay, 1857**

Records. Vrangal Bay: sta. 10, 13, 14, 20, 25.

Occurrence. Empty shells were taken in 4.5 – 17.5 m, in mud and sand.

M. e. 6 s.

Subfamily Cryptomyinae Habe, 1977

***Cryptomya busoensis* Yokoyama, 1922**

Records. Middle Primorye: sta. 36.

Occurrence. Empty shell was found in Dzhigit Bay in 18 m, on rocky bottom.

Remarks. This is the first record of *C. busoensis* in middle Primorye. According to Scarlato (1981), this species has been known only from Possjet Bay (south-western part of Peter the Great Bay). Evseev (1981) recorded *C. busoensis* from the Holocene deposits of Primorye.

M. e. 1 s.

Family Corbulidae Lamarck, 1818  
Subfamily Corbulinae Lamarck, 1818

***Anisocorbula venusta* (Gould, 1861)**

Records. Middle Primorye: sta. 27, 29, 35, 36, 41.

Occurrence. Live mollusks were taken in Oprichnik, Plastun, and Dzhigit Bays, and near Cape Tumannyi at total bathymetric range of 0.5 – 18 m, on rocky bottom and in sand covered by sea-grass *Phyllospadix*.

Remarks. Dzhigit Bay is a new northern locality of *A. venusta* in Primorye. According to Scarlato (1981), it has been known as far north as Olga Bay.

M. e. 10 s.

Superfamily Hiatelloidea Gray, 1824  
Family Hiatellidae Gray, 1824

***Hiatella arctica* (L., 1767)**

Records. Middle Primorye: sta. 36, 37, 39–41.

Occurrence. Empty shells were taken in Rudnaya, Dzhigit, and Udobnaya Bays, and near Cape Titova at total bathymetric range of 2–32 m, on rocky bottom. Live mollusks were found in Udobnaya Bay in 2 m, and in 111 m (sta. 39), in muddy sand with pebbles.

M. e. 27 s.

***Panomya norvegica* (Spengler, 1793)**

Plate II, fig. 2

Records. Vrangal Bay: sta. 14; middle Primorye: sta. 41.

Occurrence. Empty shells were taken in Vrangal Bay in 7.5 m, and near Cape Titova, in 15 m, on rocky bottom.

Remarks. *P. norvegica* is recorded in middle Primorye for the first time. Evseev's (1981) *Panomya ampla* Dall from the Holocene deposits of Primorye is most likely *P. norvegica* or *P. nipponica* Nomura et Hatai, 1935.

M. e. 2 s.

Subclass Anomalodesmacea Superfamily Pandoroidea Rafinesque, 1815  
Family Lyonsiidae Fischer, 1887

***Agriodesma navicula* (Adans et Reeve, 1850)**

Records. Middle Primorye: sta. 41, 42.

Occurrence. Live mollusks were taken in Sokolovskaya Bay, and near Cape Titova in 2 – 15 m, on rocky bottom, among sea-grass bed *Phyllospadix*.

M. e. 2 s.

## Family Pandoridae Rafinesque, 1815

***Pandora (Heteroclidus) pulchella* Yokoyama, 1926**

Plate II, figs. 7, 10

Records. Vrangal Bay: sta. 17.

Occurrence. Live specimen was taken in 11.5 m, in sandy mud.

M. e. 1 s.

***Pandora (Heteroclidus) wardiana* A. Adams, 1859**

Records. Middle Primorye: sta. 39.

Occurrence. Live mollusks were taken in 111 m, in muddy sand with pebbles.

M. e. 2 specimens.

## Family Thraciidae Stoliczka, 1870

***Thracia itoi* Habe, 1961**

Plate II, fig. 9

Records. Vrangal Bay: sta. 31.

Occurrence. Empty shells were taken in 7 m, among pebbles with sand.

M. e. 2 s.

**DISCUSSION**

A total of 58 species of bivalves were identified from the two areas studied in the Primorye Territory, continental coast of the Sea of Japan (Table 2). Thirty-six and 37 species were found in Vrangal Bay and along the coast of middle Primorye, respectively. *Cadella lubrica* (Gould, 1861) (Tellinidae) can be added to the list of mollusks of Nakhodka Bay based on the examination of collections of the ZMFU (Darkina & Lutaenko, 1996). In comparison, over 130 bivalve species inhabit entire Peter the Great Bay, and over 110 species are known from the Northern Primorye District (Scarlato, 1981) which includes the coast of Primorye north of Cape Povorotny (the eastern boundary of Peter the Great Bay), the Tatarsky (Mamiya) Strait and the coast of north-western Sakhalin. The total number of bivalves in Primorye is still unknown. Romeyko (1985) mentioned 114 species and subspecies of bivalves from the northern part of the Sea of Japan, but she did not present a precise species list.

In Vrangal Bay, samples containing mollusks were taken from soft bottoms, while samples from middle Primorye were taken mainly on rocky bottoms by the SCUBA-diving method. Thus, molluscan lists for both areas are impoverished due to different sampling techniques. Nevertheless, we have undertaken an attempt to consider some ecological, faunal, and biogeographical peculiarities of these areas based on the molluscan data obtained.

The most common species of bottom molluscan communities in Vrangal Bay are *Macoma scarlatoi* Kafanov et Lutaenko, 1997, *Axinopsida subquadrata* (Adams, 1862), *Clinocardium californiense* (Deshayes, 1839), *Raeta pulchella* (Adams et Reeve, 1848), *Callithaca adamsi* (Reeve, 1863), *Liocyma fluctuosa* (Gould, 1841), and *Theora fragilis* A. Adams, 1855. Some of these were chiefly represented by empty shells (*M. scarlatoi*, *C. adamsi*, etc.), but the presence of live specimens indicates wide distribution of these species in the bay. The most abundant bivalve was the small semelid *Th. fragilis*. It was found in the bathymetric range of 4.5 – 25 m at nine stations, commonly in large numbers. *Th. fragilis*

serves as an indicator of organic pollution in some coastal areas of Korea (Hong et al., 1994; Lim et al., 1995) and Japan (Yokoyama et al., 1996). For example, in Chinhae Bay (the southern coast of Korea) the population density of this species appeared to be related to the sediment organic carbon content and increased with the organic content of sediments (Lim et al., 1995). In Gokasho Bay (the Pacific coast of Japan), *Th. fragilis* expanded its range from the innermost part to the central part of the bay due to eutrophication when compared to a previous survey conducted in 1941 (Yokoyama et al., 1996). The coastal area of Vrangal Bay is occupied by Port Vostochny, the largest Russian Far East commercial port and industrial complex. This probably leads to a rapid modification of benthic communities of Vrangal Bay over the past few decades and changes in abundance and local distributions of several molluscan species as illustrated by *Th. fragilis*.

Another important ecological and faunal feature of Vrangal Bay are cold-water and relatively cold-water mollusks occurring in shallow water. For instance, *L. fluctuosa*, *Serripes groenlandicus* (Mohr, 1786), *Panomya norvegica* (Spengler, 1793), and *Mya truncata* L., 1758 are typical boreal-arctic species commonly found in mid- or low-subtidal zones at temperate latitudes but in high latitudes they inhabit upper-subtidal or even intertidal zones. This phenomenon called submergence (occurrence of cold-water species at greater depths in the low-latitude margin of their range) is quite common in temperate latitudes (Dodd & Stanton, 1981) and can be illustrated for the species mentioned above. According to Klimova (1974, 1975) and Scarlato (1981), *L. fluctuosa* occurs in the north-western part of the Sea of Japan at depths greater than 30–50 m, and *S. groenlandicus* is generally found in Peter the Great Bay at a depth of 50–60 m. *P. norvegica* was recorded in Far Eastern seas at depths below 30 m; Scarlato (1981) also mentioned finding this species (young specimens) at 10–12 m in Peter the Great Bay but these records, in fact, refer to an allied species, *Panomya nipponica* Nomura et Hatai, 1935. In order to find the pattern of bathymetric distribution of mollusks collected in our study, we compiled data on their depth ranges in different parts of Russian, Korean and Japanese sides of the Sea of Japan, based upon available literature sources (Tables 3, 4). The results of comparison will be discussed further.

Thus, Vrangal Bay is characterized by relatively cold-water conditions reflected in the faunal composition of mollusks. This is quite surprising since many warm-water species of the subtropical or even tropical nature commonly inhabit semi-enclosed bays and head parts of large embayments in Peter the Great Bay. Golikov & Scarlato (1967) and Scarlato (1981) have shown that this phenomenon can be explained by the intense summer warming which is necessary for successful reproduction of warm-water species, and results in the formation of stable groups with nearly annual reproduction. Winter cooling in itself does not prevent subtropical fauna from living in temperate latitudes (see Scarlato, 1981). An additional reason for the existence of warm-water species in semi-enclosed bays of Peter the Great Bay was the immense warming during the Middle Holocene (climatic optimum of the Holocene) that created the possibility of large-scale nearshore migrations of tropical-subtropical and subtropical mollusks to northern areas of the Sea of Japan (Lutaenko, 1991), and related changes in the current system - significant increase of warm stream activity and a northward shift of the front of the warm East Korean Current (Taira, 1995; Taira & Lutaenko, 1993). The molluscan fauna of Vrangal Bay seems to be the exception from the general rule of concentration of warm-water species in semi-enclosed bays of Peter the Great Bay. Japanese malacologists (cited after Scarlato, 1981) found that along the Pacific coast of Japan the molluscan fauna of bays comprises cold-water elements and can be regarded as more cold-water when compared to the fauna of the open coast. This is due to the warm Kuroshio Current creating suitable conditions for subtropical species in open areas and not influencing the hydrological regime inside the bays. In the case

Table 2. Species list of bivalve mollusks found in Vrangal Bay and along the middle Primorye coast.

Species	Vrangal Bay	Middle Primorye
1. <i>Nucula ovatotruncata</i>	+	
2. <i>Acila insignis</i>	+	
3. <i>Nuculana sadoensis</i>		+
4. <i>Yoldia johanni</i>	+	+
5. <i>Yoldia notabilis</i>	+	
6. <i>Vilasina pillula</i>		+
7. <i>Crenomytilus grayanus</i>	+	+
8. <i>Mytilus edulis</i>	+	
9. <i>Modiolus kurilensis</i>	+	
10. <i>Glycymeris yessoensis</i>	+	
11. <i>Arca boucardi</i>	+	+
12. <i>Crassostrea gigas</i>	+	
13. <i>Pododesmus macrochisma</i>		+
14. <i>Chlamys albida</i>		+
15. <i>Chlamys</i> cf. <i>behringiana</i>		+
16. <i>Chlamys chosenuca</i>		+
17. <i>Chlamys swifti</i>		+
18. <i>Parvamussium alaskense</i>		+
19. <i>Mizuhopecten yessoensis</i>	+	+
20. <i>Felaniella usta</i>	+	+
21. <i>Axinopsida subquadrata</i>	+	+
22. <i>Kellia japonica</i>		+
23. <i>Mysella</i> (?) sp.		+
24. <i>Cyclocardia crassidens</i>		+
25. <i>Clinocardium californiense</i>	+	+
26. <i>Clinocardium ciliatum</i>		+
27. <i>Clinocardium likharevi</i>		+
28. <i>Serripes groenlandicus</i>	+	+
29. <i>Macra chinensis</i>		+
30. <i>Spisula sachalinensis</i>		+
31. <i>Raeta pulchella</i>	+	
32. <i>Cadella lubrica</i>		+
33. <i>Macoma calcarea</i>		+
34. <i>Macoma incongrua</i>	+	
35. <i>Macoma scarlati</i>	+	
36. <i>Macoma golikovi</i>	+	
37. <i>Macoma middendorffi</i>	+	+
38. <i>Nuttallia ezonis</i>	+	
39. <i>Theora fragilis</i>	+	
40. <i>Siliqua alta</i>	+	
41. <i>Mercenaria stimpsoni</i>	+	+
42. <i>Callithaca adamsi</i>	+	
43. <i>Prothotaca jedoensis</i>	+	+
44. <i>Prothotaca euglypta</i>	+	+
45. <i>Ruditapes philippinarum</i>	+	
46. <i>Liocyma fluctuosa</i>	+	+
47. <i>Callista brevisiphonata</i>	+	+
48. <i>Mya truncata</i>	+	

Table 2. (Continued)

Species	Vrangel Bay	Middle Primorye
49. <i>Mya uzenensis</i>	+	
50. <i>Mya japonica</i>	+	
51. <i>Cryptomya busoensis</i>		+
52. <i>Anisocorbula venusta</i>		+
53. <i>Hiatella arctica</i>		+
54. <i>Panomya norvegica</i>	+	+
55. <i>Agriodesma navicula</i>		+
56. <i>Pandora pulchella</i>	+	
57. <i>Pandora wardiana</i>		+
58. <i>Thracia itoi</i>	+	

of Vrangel Bay, the relatively cold-water character of its bivalve mollusks can be attributed to the probable influence of the cold Primorskoye Current that penetrates into the eastern, more exposed bays of Peter the Great Bay, as exemplified by Vostok and Nakhodka Bays rather than to the highly indented coast and protected western embayments, namely, Possjet, Amur and Ussuri Bays. Ivaschenko (1993) noted that the Primorskoye Current influences the eastern part of Peter the Great Bay and some open areas around islands in the Bay, but Amur and Ussuri Bays remain outside of its influence, and Stepanov (1976) observed the upwelling of deep cold water with minimum temperatures of 3 – 4°C in Vostok Bay even in August. Therefore, a combination of such features as geomorphological indentation of the coastline, local hydrological regime (intense summer warming) and the influence of currents makes it possible to recognize two types of embayments within Peter the Great Bay - semi-enclosed bays inhabited by relic mid-Holocene thermophilous molluscan fauna and those dominated by temperate and relatively cold-water (boreal-arctic in zonal-geographical terminology) fauna. In neighboring Vostok Bay, similar in hydrological conditions to Nakhodka Bay, only one extinct Holocene warm-water species, *Meretrix lusoria* (Roding, 1798), Veneridae (Evseev, 1976) was found, while in Possjet, Amur and Ussuri Bays, three extinct thermophilous bivalves were found - two species of the genus *Anadara*, Arcidae and *M. lusoria* (Lutaenko, 1993; Rakov & Lutaenko, 1997). Other tropical-subtropical and subtropical mollusks still existing in Peter the Great Bay as remnants of the mid-Holocene warming - *Dosinia penicillata* (Reeve, 1850), *Macra veneriformis* Deshayes, 1853 (Mactridae), and *Trapezium liratum* (Reeve, 1843) (Trapeziidae) - also did not occur in either Nakhodka nor Vostok Bays. This supports the opinion that even during the climatic optimum of the Holocene (5000 – 6000 years B.P.), the warmest period of the post-glacial history, the eastern area of Peter the Great Bay was influenced by a cold current preventing the penetration of warm-water fauna into this area.

Molluscan fauna of middle Primorye, as we mentioned, is insufficiently studied. In spite of this fact, it is not surprising that a number of species (*Vilasina pillula* Bartsch in Scarlato, 1960, *Arca boucardi* Jousseaume, 1894, *Chlamys albida* (Dall, 1906), *Ch. cf. behringiana* (Middendorff, 1849), *Clinocardium ciliatum* (Fabricius, 1790), *C. likharevi* Kafanov in Scarlato, 1981, *Cryptomya busoensis* Yokoyama, 1922, *P. norvegica*) are recorded for the first time from that area. Distributional ranges of other species (*Mizuhopecten yessoensis* (Jay, 1857), *Macra chinensis* Philippi, 1846, *Spisula sachalinensis* (Schrenck, 1861), *C. lubrica*, *Mercenaria stimpsoni* (Gould, 1861) should be extended northward along the coast of Primorye, although some



Table 3. Bathymetric ranges of bivalve mollusks obtained in present study as compared to other regions of the Sea of Japan (Russian coast).

Species	Area I	Area II	Area III	In total
1. <i>Nucula ovatotruncata</i>	3 – 62 [1]	4.5– 17.5		3 – 62
2. <i>Acila insignis</i>	5 – 70	4 – 7.5		4 – 70
3. <i>Nuculana sadoensis</i>	23 – 80 and deeper [2]	111	220 [2]	23 – 220
4. <i>Yoldia johanni</i>	5 – 28	4.5– 15		4.5– 28
5. <i>Yoldia notabilis</i>	2 – 68 [3]	10 – 17.5		2 – 68
6. <i>Vilasina pillula</i>	2.5– 21	0.5– 20	1 – 60	0.5– 60
7. <i>Crenomytilus grayanus</i>	1 – 60	0.5– 12	0 – 80	0.5– 80
8. <i>Mytilus edulis</i>	0 – 10	7.5– 25	0 – 5	0 – 25
9. <i>Modiolus kurilensis</i>	2 – 22 [4]	7	5 – 80 [4]	2 – 80
10. <i>Glycymeris yessoensis</i>	1.5– 10	9	? – 44	1.5– 44
11. <i>Arca boucardi</i>	3 – 10	10 – 18	7 – 80	3 – 80
12. <i>Crassostrea gigas</i>	1.5– 3	4 – 25		1.5– 25
13. <i>Pododesmus macroshisma</i>	25	9 – 32	15 – 150	9 – 150
14. <i>Chlamys albidia</i>		111		111
15. <i>Chlamys behringiana</i>		111	40 – 100 [5]	40 – 111
16. <i>Chlamys chosonica</i>	13 – 2030 [6]	111	40 – 200 [6]	13 – 2030
17. <i>Chlamys swifti</i>	2 – 46 [7]	0.5– 20	20 – 75	0.5– 75
18. <i>Parvamussium alaskense</i>	100 – 350	111	1 – 220	1 – 350
19. <i>Mizuhopecten yessoensis</i>	1.5– 80	17.5	15 – 40	1.5– 80
20. <i>Felaniella usta</i>	1.5– 30	3.5– 15	5 – 44	1.5– 44
21. <i>Axinopsida subquadrata</i>	6 – 62	4 – 25		4 – 62
22. <i>Kellia japonica</i>		1 – 15	23 – 120	1 – 120
23. <i>Mysella</i> (?) sp.		15		15
24. <i>Cyclocardia crassidens</i>		32 – 50	100 – 150	32 – 150
25. <i>Clinocardium californiense</i>	4 – 49 [7, 8]	3 – 30		3 – 49
26. <i>Clinocardium ciliatum</i>		111		111
27. <i>Clinocardium likharevi</i>	45 – 62	111	100	45 – 111
28. <i>Serripes groenlandicus</i>	17 – 62	4.5– 111	60 – 120	4.5– 120
29. <i>Mactra chinensis</i>	1.5– 16	9 – 12	16	1.5– 16
30. <i>Spisula sachalinensis</i>	1.5– 4			1.5– 4
31. <i>Raeta pulchella</i>	5 – 28	4.5– 25		4.5– 28
32. <i>Cadella lubrica</i>	4 – 30	6	down to 180	4 – 180
33. <i>Macoma calcarea</i>	16 – 62 [9]	111	150 – 280	16 – 280
34. <i>Macoma incongrua</i>	0 – 6	11.5		0 – 11.5
35. <i>Macoma scarlatoi</i>	10 – 65 [10]	4.5– 25		4.5– 65
36. <i>Macoma golikovi</i>		11		11
37. <i>Macoma middendorffi</i>		7		7
38. <i>Nuttallia ezonis</i>		4 – 7.5		4 – 7.5
39. <i>Theora fragilis</i>	3 – 18 [11]	4.5– 25		3 – 26
40. <i>Siliqua alta</i>	10 – 20	7.5		7.5– 20
41. <i>Mercenaria stimpsoni</i>	2 – 45	4 – 9		2 – 45
42. <i>Callithaca adamsi</i>	1 – 35	4 – 17.5	5 – 17	1 – 35
43. <i>Protothaca jedomensis</i>	1	3 – 7		1 – 7
44. <i>Protothaca euglypta</i>	0 – 1.5	3 – 18	5 – 15	0 – 18
45. <i>Ruditapes philippinarum</i>	0 – 16 [12]	4 – 6		0 – 16
46. <i>Liocyma fluctuosa</i>	23 – 65	4 – 47	60 – 220	4 – 220
47. <i>Callista brevisiphonata</i>	2 – 57 [13]	9 – 12	40 – 80	2 – 80

Table 3. (Continued)

Species	Area I	Area II	Area III	In total
48. <i>Mya truncata</i>		11.5		11.5
49. <i>Mya uzenensis</i>	down to 20 [14]	4 - 9		4 - 20
50. <i>Mya japonica</i>	1 - 14 [15]	4.5- 17.5		1 - 17.5
51. <i>Cryptomya busoensis</i>	5 - 7	18		5 - 18
52. <i>Anisocorbula venusta</i>	1 - 15 [7]	0.5- 18	20 - 40 [16]	0.5- 40 (840)
53. <i>Hiatella arctica</i>	0 - 150 [17]	2 - 111	23 - 40	0 - 150
54. <i>Panomya norvegica</i>		7.5- 15		7.5- 15
55. <i>Agriodesma navicula</i>	0 - 1.5 [18]	2 - 15		0 - 15
56. <i>Pandora pulchella</i>	4.5- 57 [7]	11.5		4.5- 57
57. <i>Pandora wardiana</i>		111		111
58. <i>Thracia itoi</i>	14	7		7 - 14

Comments for Table 3:

a) Areas and References: Area I - Peter the Great Bay including Possjet Bay and area of the Far East State Marine Reserve (Razin, 1934; Golikov and Scarlato, 1967; Scarlato, 1981; Moskaletz, 1984); Area II - present study (Vrangel Bay and middle Primorye); Area III - Moneron Island (Romeyko and Kamenev, 1985).

b) Data on bathymetric ranges include findings of both alive and dead (empty shells) mollusks.

c) Numerals in square brackets:

[1] - as *Ennucula cyrenoides* (Kuroda) in Golikov and Scarlato, 1967; [2] - as *Nuculana pernula sadoensis* (Yokoyama); [3] - as *Yoldia keppeliana pseudonotabile* Scarlato in Scarlato, 1981; [4] - as *Modiolus difficilis* (Kuroda et Habe); [5] - as *Chlamys strategus* (Dall); [6] - as *Chlamys rosealbus* Scarlato; [7] - depth range is given for entire Primorye coast; [8] - as *Cardium (Cerastoderma) californiense* Deshayes in Razin, 1934; [9] - as *Macoma brota* Dall in Moskaletz, 1984; [10] - as *Macoma orientalis* Scarlato; [11] - as *Theora lubrica* Gould; [12] - as *Paphia philippinarum* Adams et Reeve in Razin, 1934, and *Venerupis japonica* (Deshayes) in Golikov and Scarlato, 1967; [13] - including "*Callista chinensis* (Holten)" in Golikov and Scarlato, 1967; [14] - as *Mya priapus* Tilesius in Scarlato, 1981; [15] - as *Mya arenaria japonica* Jay in Golikov and Scarlato, 1967; [16] - Scarlato (1981) mentioned that *A. venusta* was found near Moneron Island in depth 84 m; [17] - as *Hiatella arctica orientalis* (Yokoyama) in Golikov and Scarlato, 1967; [18] - as *Entodesma naviculoides* Yokoyama.

d) Empty cell means that this species is not found in this area or there are no exact data.

of them are known from coasts of Sakhalin and Hokkaido. These new records will make it possible to compare faunal properties in Far Eastern seas more precisely.

Analysis of bathymetric ranges of bivalve mollusks treated in our study and known from other localities of the Sea of Japan (Tables 3, 4) seems to indicate the following tendencies. Some warm-water species (subtropical or subtropical-lowboreal according to zonal-geographical terminology) inhabit deeper areas in the south-eastern and south-western parts of the sea, but they are found in the north-western part only in the upper subtidal zone. For example, *Acila insignis* (Gould, 1861), *Pandora wardiana* A. Adams, 1859, *Raeta pulchella* (Adams et Reeve, 1848), *C. lubrica* and some others are known along the southern coast of Korea, Niigata Prefecture and Wakasa Bay of Japan at depths to 200-300 m, while they generally are not found below 30-40 m in north-western part of the Sea of Japan. The exception are the coastal waters of Moneron Island in the northern part of the sea influenced

Table 4. Bathymetric ranges of bivalve mollusks obtained in present study and known from southern part of the Sea of Japan.

Species	Area I	Area II	Area III	Area IV	In total
1. <i>Acila insignis</i>	104–210		121–137	58–161	58–210
2. <i>Nuculana sadoensis</i>	143–145 [1]				143–145
3. <i>Yoldia johanni</i>		93– 96			93– 96
4. <i>Arca boucardi</i>			11–210	41–139	11–210
5. <i>Chlamys swifti</i>			101–108	275	101–275
6. <i>Parvamussium alaskense</i>		278–518 [2]			278–518
7. <i>Mizuhopecten yessoensis</i>			26–156 [3]	60– 83 [3]	26–156
8. <i>Felaniella usta</i>				41–161	41–161
9. <i>Axinopsida subquadrata</i>	105–205		27–332	58–161	27–332
10. <i>Clinocardium ciliatum</i>			225	130–180	130–225
11. <i>Serripes groenlandicus</i>			165–275	157–198	157–275
12. <i>Mactra chinensis</i>			37– 52	60– 94	37– 94
13. <i>Raeta pulchella</i>			5–102 [4]	39– 62 [4]	5–102
14. <i>Cadella lubrica</i>			101–151	67–125	67–151
15. <i>Macoma calcarea</i>			129–275		129–275
16. <i>Theora fragilis</i>			34– 56		34– 56
17. <i>Mercenaria stimpsoni</i>			100–210	41–161	41–210
18. <i>Callithaca adamsi</i>				87–161	87–161
19. <i>Protothaca jedoensis</i>			5– 52	126–139	5–139
20. <i>Cryptomya busoensis</i>			5– 16	80–161	5–161
21. <i>Anisocorbula venusta</i>			35–200	41–125	35–200
22. <i>Hiatella arctica</i>		93– 96 [5]	5–275 [5]	41–175 [6]	5–275
23. <i>Pandora wardiana</i>			11–300 [7]	41–200 [7]	11–300

Comments for Table 4:

a) Areas and references: Area I - Sea of Japan side of Korea (Je, 1993); Area II - Oki-Kaikyo Strait and off Hino-Misaki (Tsuchida and Hayashi, 1994); Area III - Niigata Prefecture (including Sado Isl.) (Ito, 1978, 1985, 1989); Area IV - Wakasa Bay and Hyogo Prefecture (Ito, 1967, 1990).

b) Data on bathymetric ranges include findings of both alive and dead (empty shells) mollusks.

c) Numerals in square brackets:

[1] - as *Nuculana pernula sadoensis* (Yokoyama); [2] - as *Polynemamussium alaskense* (Dall); [3] - as *Patinopecten (Mizuhopecten) yessoensis* (Jay); [4] - as *Raetellops pulchella* (Adams et Reeve); [5] - as *Hiatella orientalis* (Yokoyama); [6] - including *Hiatella orientalis* (Yokoyama); [7] - as *Pandorella wardiana* (Adams) in Ito, 1990.

d) Empty cell means that this species is not found in this area or there are no exact data.

by a warm branch of Tsushima Current where some subtropical-lowboreal species can be found to 100 m (Romeyko & Kamenev, 1985). The same feature can be demonstrated for cold-water species inhabiting deeper areas in the southern part of the Sea of Japan (see Tables 3, 4). Nishimura (1966) recognized several animal communities characterized by their distinctive faunal composition and their regular position in the vertical distribution in the sea. For example, his so-called taraba I community (subarctic sublittoral community) occupies a depth range of 150–250 m in the eastern and southern regions and inhabits shallow (5–60 m) coastal zones in the northern and north-western regions. This clearly

shows that the general tendency of submergence of relatively cold-water animals into deeper areas at the edge of their ranges can be applied to the Sea of Japan molluscan fauna. On the other hand, warm-water mollusks also submerge into deeper areas in southern part of the sea. This reflects a peculiar character of complicated current systems: the Sea of Japan is divided into two distinct areas - the south-eastern warm area washed by the Tsushima Current, and the north-western cold area affected by the Liman and Primorskoye Current (Nishimura, 1983). Further faunal studies will clarify in detail the complex biogeographical nature of the Sea of Japan.

It should be mentioned that molluscan assemblage from sta. 39 (depth 111 m), most likely, contains some subfossil shells (*Macoma calcaria* (Gmelin, 1791), *Macoma middendorffi* Dall, 1885). This sample was taken on a muddy sand bottom with numerous pebbles. Pebbly deposits are widely distributed along the coast of Primorye (so-called Primorian gravel belt in the low-subtidal zone and represent traces of an ancient Late Pleistocene coastline recognized by many geologists since 1950 (Zabelin et al., 1975; Mechetin & Ryazantsev, 1978). Taphonomic conditions of the shells prove their subfossil origin. This fact should be taken into account when considering bathymetric ranges of bivalve mollusks in the north-western part of the Sea of Japan. Evseev (1981) clearly showed that the present-day and Holocene depth distributions of some bivalve species are significantly different depending on post-glacial sea level rise. Another reason for the wide depth ranges of empty shells (as well as unusual local distribution) is the redeposition of subfossil remains resulting from the erosional action of rivers. Lutaenko (1992) studied this process on the coasts of Amur and Ussuri Bays in respect to erosion of the mid-Holocene deposits with abundant species of the genus *Anadara* - *Anadara inaequivalvis* (Bruguere, 1789), became extinct in the Late Holocene and can be used as a reliable indicator of asynchronous transportation. Among different aspects of this process, we would like to emphasize ice dispersal, i.e., freezing of shells and their fragments (both Recent and subfossil) to the lower surface of shore ice and its further transportation, primarily from semi-enclosed bays to open areas. Razin (1934) observed empty shells of oysters at a depth of 36 m in Ussuri Bay while alive oyster settlements occur in the bathymetric range of 0.5 - 7 m (Razin, 1934; Scarlato, 1981) in Peter the Great Bay. Razin (1934, p. 41) explained this phenomenon by the ice dispersal based on his direct observations of the oyster shells during 1924 - 1932 along the coast of Amur Bay. We found in Possjet Bay rare valves of an estuarine species, *Corbicula japonica* Prime, 1864 (Corbiculidae) in beach drift of open areas which were most likely transported from river mouths situated at a distance of 10 - 15 km (Lutaenko, 1990; 1994b). It is suggested that the unusually wide depth ranges of *Mytilus edulis* L., 1758 (7.5 - 25 m) and *Crassostrea gigas* (Thunberg, 1793) (4 - 25 m) represented by empty shells in Vrangal Bay, might be explained by the same reasons. *M. edulis* inhabits mainly the intertidal zone in Peter the Great Bay influenced by winter shore ice, or its shells originate from biofouling communities in Port Vostochny.

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**Explanations to Plates I-II****Plate I**

Figs. 1, 2. *Chlamys* (*Chlamys*) cf. *behringiana* (Middendorff, 1849). Left and right valves, length 40 mm. Sea of Japan, middle Primorye, sta. 39, depth 111 m. MIMB.

Fig. 3. *Chlamys* (*Chlamys*) cf. *behringiana* (Middendorff, 1849). Right valve, length 56 mm. Sea of Japan, middle Primorye, sta. 39, depth 111 m. MIMB.

Fig. 4. *Macoma* (*Macoma*) *middendorffi* Dall, 1885. Right valve, length 36 mm. Sea of Japan, Peter the Great Bay, Boysman Bay, beach drift. ZMFU no. 11120/Bv - 1220.

Fig. 5. *Chlamys* (*Chlamys*) *chosenica* Kuroda, 1932. Left valve, length 66 mm. Sea of Japan, middle Primorye, sta. 39, depth 111 m. MIMB.

Fig. 6. *Mya* (*Mya*) *truncata* L., 1758. Right valve, length 60 mm. Sea of Japan, Nakhodka Bay, Vrangal Bay, sta. 19, depth 11.5 m. MIMB.

**Plate II**

Fig. 1. *Macoma* (*Macoma*) *middendorffi* Dall, 1885. Right valve, length 34 mm. Sea of Japan, Peter the Great Bay, Popov Island, beach drift. ZMFU no. 10147/Bv - 582.

Fig. 2. *Panomya norvegica* (Spengler, 1793). Left valve, length 43 mm. Sea of Japan, Nakhodka Bay, Vrangal Bay, sta. 14, depth 7.5 m. MIMB.

Fig. 3. *Liocyma fluctuosa* (Gould, 1841). Right valve, length 27 mm. Sea of Japan, Nakhodka Bay, Vrangal Bay, sta. 14, depth 7.5 m. MIMB.

Fig. 4. *Clinocardium* (*Keenocardium*) *californiense* (Deshayes, 1839). Left valve, length 37 mm. Sea of Japan, Nakhodka Bay, Vrangal Bay, sta. 29, depth 12.5 m. MIMB.

Fig. 5. *Serripes groenlandicus* (Mohr, 1786). Left valve, length 66 mm. Sea of Japan, Nakhodka Bay, Vrangal Bay, sta. 17, depth 11.5 m. MIMB.

Fig. 6. *Nuttallia ezonis* (Kuroda et Habe, 1955). Left valve, length 28 mm. Sea of Japan, Nakhodka Bay, Vrangal Bay, sta. 18, depth 4 m. MIMB.

Figs. 7, 10. *Pandora* (*Heteroclidus*) *pulchella* Yokoyama, 1926. Right and left valves, length 43 mm. Sea of Japan, Nakhodka Bay, Vrangal Bay, sta. 17, depth 11.5 m. MIMB.

Fig. 8. *Macoma* (*Macoma*) *scarlatoi* Kafanov et Lutaenko, 1997. Right valve, length 36 mm. Sea of Japan, Nakhodka Bay, Vrangal Bay, sta. 25, depth 12.5 m. MIMB.

Fig. 9. *Thracia itoi* Habe, 1961. Right valve, length 43 mm. Sea of Japan, Nakhodka Bay, Vrangal Bay, sta. 31, depth 7 m. MIMB.

Fig. 11. *Macoma* (*Macoma*) *golikovi* Scarlato et Kafanov, 1988. Right valve, length 35 mm. Sea of Japan, Nakhodka Bay, Vrangal Bay, sta. 5, depth 11 m. MIMB.

